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Distribution, abundance and habitat evaluation of Asian vultures along Kaligandaki Corridor, Nepal

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Abstract Scavengers perform crucial ecological role by consuming animal carrion and thereby controlling the spread of harmful diseases. In recent decades, vulture species populations have declined across Southeast Asia due to anthropogenic disturbances such as indirect poisoning, land-use change, electrocution and shortage of carrions. This study was conducted aiming to assess the distribution, abundance, and habitat evaluation of Asian vultures in Kaligandaki Corridor, Nepal. Field observations were conducted through the birding routes, visit of nesting and roosting sites and fixed-point surveys. A questionnaire survey was also done to identify people's perception of the status and threats on Asian vultures. In total, 99 individuals representing five vulture species were recorded in total 21 observation points along the Kaligandaki River Corridor (57 individuals in 12 different points during the summer visit and 42 individuals in nine different points during the winter visit). Remarkably only two species, White-rumped Vulture *(Gyps bengalensis)* and Red-headed Vulture *(Sarcogyps calvus)*, were recorded at Khaireni Community Forest (KCF) with a total of 63 individuals (37 individuals in summer and 26 in winter). Vulture sightings and abundance were relatively higher during summer than in winter. The White-rumped Vulture was the most abundant species and Red-headed Vulture was found to be the least abundant species recorded in both seasons in the study area. Only the nest of White-rumped Vulture was observed at KCF. Simal *(Bombax ceiba)* was found to be the most used tree species for nesting by vultures. Vultures were found in highest densities in the forest habitat followed by agricultural land, riverbank, settlements and rocky areas. Distance to water, distance to forest and distance to agricultural land showed positive association with abundance of vulture in summer whereas distance to settlement land, distance to Vulture Safe Feeding Sites (VSFS) showed significant association to abundance of vulture species during winter. Food scarcity, habitat loss, lack of conservation awareness, use of chemicals and hunting were some of the threats for population decline of vultures in the area. For the long-term conservation of vulture species, community-based conservation programs, awareness campaigns and provision of economic incentives to local people should be conducted in all its range areas by government authority and concerned organizations.

Keywords: distribution, habitat evaluation, Asian vultures, Kaligandaki Corridor

Összefoglalás A dögevők az állati hullák elfogyasztásával döntő ökológiai szerepet töltenek be, és ezáltal megakadályozzák a káros betegségek terjedését. Az elmúlt évtizedekben a keselyűfajok populációi Délkelet-Ázsia-szerte csökkentek az olyan antropogén tényezők miatt, mint a közvetett mérgezés, a földhasználat megváltozása, az áramütés és a dögök hiánya. A tanulmány célja az volt, hogy felmérje az ázsiai keselyűk elterjedését, abundanciáját és élőhelyét a nepáli Kaligandaki folyosón. A terepi megfigyeléseket a madármegfigyelési útvonalakon, a fészkelő- és éjszakázóhelyeken tett látogatásokon és a fixpontos felméréseken keresztül végeztük. Kérdőíves felmérést is végeztünk annak megállapítására, hogy az emberek hogyan vélekednek az ázsiai keselyűk helyzetéről és veszélyeztetettségéről. A Kaligandaki folyosó mentén összesen 21 megfigyelési ponton 99 egyedet regisztráltunk, amelyek öt keselyűfajt képviseltek (a nyári látogatás során 12 különböző ponton 57 egyedet, a téli látogatás során pedig kilenc különböző ponton 42 egyedet). Figyelemre méltó, hogy a Khaireni közösségi erdőben (KCF) csak két fajt, a bengál keselyűt *(Gyps bengalensis)* és a pirosfejű keselyűt *(Sarcogyps calvus)* észlelték, összesen 63 egyeddel (37 egyedet a nyári és 26-ot a téli megfigyelési időszakban). A keselyű-észlelések és a keselyűk száma viszonylag magasabb volt nyáron, mint télen. A bengál keselyű volt a leggyakoribb, a pirosfejű keselyű pedig a legritkább faj, amelyet mindkét évszakban észleltünk a vizsgált területen. A KCF-ben csak a bengál keselyű fészkét figyeltük meg. A vörös selymes gyapotfa *(Bombax ceiba)* bizonyult a keselyűk által fészkelésre leginkább használt fafajnak. A keselyűk legnagyobb számban az erdei élőhelyeken voltak jelen, majd a mezőgazdasági területek, a folyópartok, a települések és a sziklás területek következtek. A víztől, az erdőtől és a mezőgazdasági területtől való távolság pozitív összefüggést mutatott a keselyűk nyári gyakoriságával, míg a településektől és a keselyűk biztonságos táplálkozóhelyeitől való távolság szignifikáns összefüggést mutatott a keselyűfajok téli gyakoriságával. A keselyűk populációjának csökkenését a területen többek között a táplálékhiány, az élőhelyvesztés, a természetvédelmi tudatosság hiánya, a vegyszerek használata és a vadászat fenyegette. A keselyűfajok hosszú távú megőrzése érdekében a kormányzati hatóságoknak és az érintett szervezeteknek közösségi alapú védelmi programokat, tudatosságnövelő kampányokat és gazdasági ösztönzőket kell nyújtaniuk a helyi lakosságnak az összes elterjedési területen.

Kulcsszavak: elterjedés, élőhelyértékelés, ázsiai keselyűk, Kaligandaki folyosó

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Introduction

Nepal, due to its unique geographic location and wide range of altitudes and climatic zones, is known for its rich biodiversity, and including a high number of bird species (Gurung *et al.* 2024). Vultures are scavengers, therefore perform an important ecological role by reducing pollution and disease and preserving a clean environment. All continents except Antarctica and Oceania are home to these medium- to large-sized birds, which are members of the Accipitridae family (del Hoyo *et al.* 1992). Some societies depend on vultures to dispose of human remains, especially in areas like Manang and Mustang of Nepal where sky burials are practiced (Bhushal & Rana 2020).

Nepal is home to nine of the world's twenty-three vulture species, including highly endangered ones like the Slender-billed Vulture (SBV) *(Gyps tenuirostris)* and the White-rumped Vulture (WRV) *(Gyps bengalensis)*. The Himalayan Griffon (HG) *(Gyps himalayensis)*, Cinerous Vulture *(Aegypius monachus)*, Egyptian Vulture (EV) *(Neophron percnopterus)*, Bearded Vulture (BV) *(Gypaetus barbatus)*, Indian Vulture *(Gyps indicus)*, Red-headed Vulture (RHV) *(Sarcogyps calvus)*, and Griffon Vulture (GV) *(Gyps fulvus)* are among the other species (BCN 2011). However, several of these species migrate, and six of them breed locally. Four species are listed as Critically Endangered, one as Endangered, and three as Near Threatened by the International Union for Conservation of Nature (IUCN 2024).

From tall trees in forests to rocky cliffs and open countryside, Asian vultures can be found in a wide range of habitats (Thakur & Narang 2012, Harris 2013, Haenn *et al.* 2014). Geographical and climatic conditions, food availability, and human disturbances all affect their hunting and breeding habits (Donázar *et al.* 1993). However, the veterinary medication diclofenac, which has been demonstrated to be poisonous to these species, was primarily responsible for the sharp drop in vulture populations that occurred between 1997 and 2007 (Oaks *et al.* 2004, Shultz *et al.* 2004). Food shortages, indirect poisoning, habitat degradation, and electrocution are further contributing factors (Chaudhary *et al.* 2019, Ghimire *et al.* 2019a).

The collapse of Asian vulture populations has triggered significant ecological and economic consequences. The decline has led to a rise in feral dogs and other scavengers, heightening health risks for both humans and wildlife. Additionally, local communities now seek alternative methods for carcass disposal, impacting businesses reliant on bone collection and cattle skinning (Prakash *et al.* 2003).

The rate of Asian vulture population loss appears to have slowed and may even be reversing, according to recent studies (Paudel *et al.* 2017, Galligan *et al.* 2020). Public awareness efforts and conservation measures like the creation of Vulture Safe Zones (VSZ) and Vulture Safe Feeding Sites (VSFS) have been essential in resolving this issue (Bhusal 2018). Governmental and non-governmental organizations have been attempting to develop Vulture Restaurants since 2000. In 2006, the first vulture restaurants were opened in Pithauli, Nawalparasi, Nepal and the first vulture breeding center was constructed in Chitwan National Park. Diclofenac Free Zones had been established in sixteen districts by 2010.

Since vulture restaurants and breeding facilities have been developed in places like Chitwan, Nawalparasi, and the lowland Terai regions, most Nepal's vulture conservation efforts have been focused there. But despite being a vital home for a variety of vulture species, the Kaligandaki Corridor did not receive much conservation attention. Despite having large forest patches, cliffs that vultures may nest on, and a wealth of biodiversity, not much research has been done to evaluate the Asian vulture population status, breeding habits, and main concerns in this area.

By thoroughly evaluating the Asian vultures' range, nesting locations, and conservation issues in the Kaligandaki Corridor, this study seeks to close this research gap. The results will offer the baseline information required to develop conservation plans and guarantee these ecologically important species' long-term existence. Additionally, vulture protection in Nepal will be strengthened by involving local populations in conservation activities and locating possible locations for new conservation projects. Additionally, by offering evidence-based suggestions for extending vulture conservation beyond the existing designated sites, this study will assist stakeholders and conservation policymakers.

Material and Methods

Study area

The study area lies in the southern part of Palpa district, northern part of Syangja district, northeast part of Tanahun district and eastern part of Nawalparasi – East district of Nepal. The study area covers a total of 38 km with latitude of 27.86477°–27.84177° and longitude of 83.85203°–84.16805° within elevation of 303–455 m above sea level. More than half of the area lies in Rampur Municipality, Palpa District. A community managed vulture safe feeding site, Khaireni Community Forest (KCF) 27.8793° N and 83.84788° E, elevation of 333 m from sea level was also included in the study area. It lies by the side of Kaligandaki River with a large number of mature trees of simal *(Bombax ceiba)* in which vultures roost and build nests. The site consists of two blocks, such as western and eastern blocks, separated by a flood channel. The dead livestock comes from nearby villages to the feeding site.

The Kaligandaki River is especially important for its biodiversity along this landscape. The Kaligandaki River severs through Nepal's varied geographical zones and thus presents an excellent opportunity to examine the bird, fish, and flora distribution. There are various forest patches on both sides of river with cliffs and scattered human settlements, which provides favorable habitat for different vulture species.

The landscape also includes biodiversity important areas including protected areas and protection forests (Gautam & Baral 2013). These areas provide refuge for globally significant wildlife species, endemic flora and serve as watersheds and micro-organisms. The area has been included in the list of Important Bird and Biodiversity Areas of Nepal (Baral & Inskipp 2004) *(Figure 1)*.

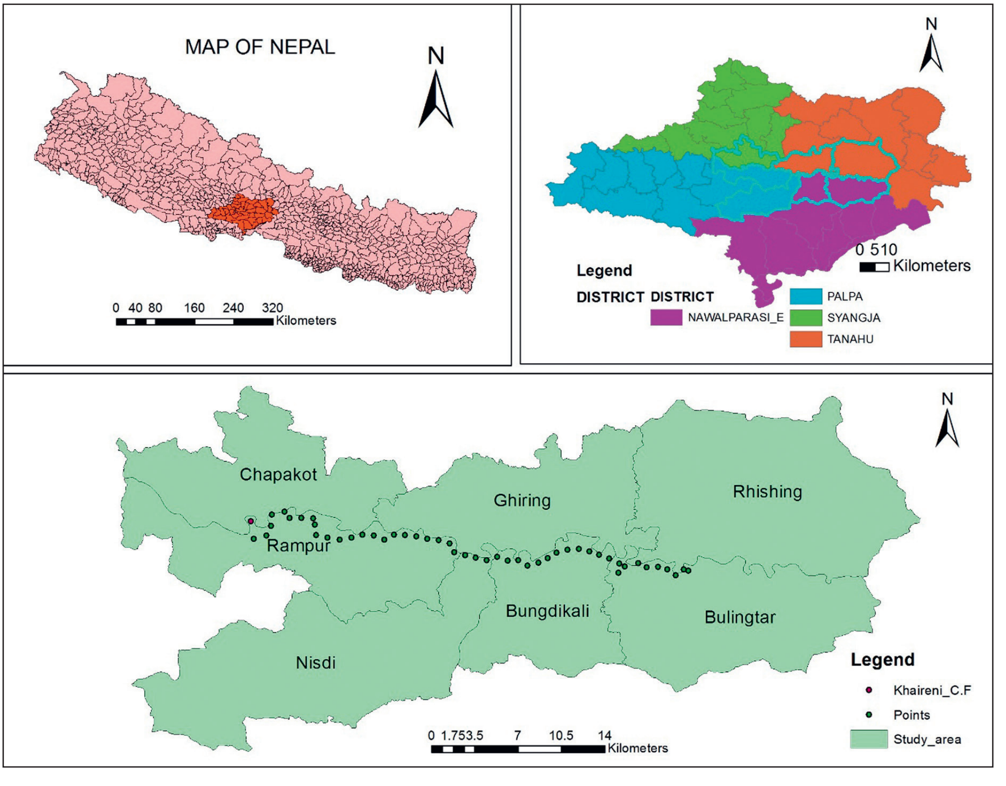

Figure 1. Map of study area with their GPS point location
1. ábra A vizsgálati terület térképe a GPS pontokkal

The area has a subtropical monsoon climate. The study area comprises temperate, dry winter and scorching summer; hot dry from February to May, monsoon from June to August and cool-dry from September to January. The climate of the district varies from subtropical in lower hills and valleys to sub-humid in the mid-hills and gets temperate in high hills.

The major dominant vegetation comprises simal, khair *(Acacia catechu)*, karma *(Adina cordifolia)*, sal *(Shorea robusta)*, katus *(Castanopsis indica)*, chilaune *(Schima wallichi)*, tuni *(Toona ciliata),* and saaj *(Terminalia tomentosa)*. Mammals like Golden Jackal *(Canus aureus)*, Clouded Leopard *(Neofelis nebulosa)*, Wild Boar *(Sus scrofa)*, Indian Crested Porcupine *(Hystix indica)* and Indian Hare *(Lepus nigricollis)* are found in the area.

Vulture survey

The fixed-point count method is mostly used in bird observation because large birds have a large foraging area. So, to minimize disturbances from observers, cover large area and to standardize the data collection we used fixed-point count method for bird survey (Waltert *et al.* 2004)**.**

We set up a total of 48-fixed point stations to observe the vulture species and their habitats. A preliminary survey was conducted to identify the locations where animal farming is mostly done. As the vultures are feeding mostly on dead livestock, sightings of vulture species during preliminary visit were mostly in the area between the Khairani Community Forest and Bulingtar. We purposefully selected the Khairani Community Forest as a fixed-point count station for vulture observation because it was a VSFS and is an obvious nesting site for these species. Considering the first fixed-point counting station we laid down 45 other fixed-point count stations starting from Khairani Community Forest to Bulingtar at the interval of 400 meters between the nearby stations to reduce repeated counting of vultures. We surveyed vultures in these fixed-point count stations twice: in November 2019 (summer) for 7 days and in June 2020 (winter) for seven days. We used Garmin Etrex 10 global positioning system (GPS) device to locate the point count stations.

We recorded the elevation and GPS location wherever vulture species are sighted. The number of various vulture species, number, nesting sites, GPS location and time was noted on each site for each season. The field guidebook 'Birds of Nepal' (Grimmett *et al.* 2016) was used for identification of vultures.

In each fixed-point station, vulture species seen were noted for 20 minutes. The area was scanned with the help of binoculars (Bushnell 8×10) to observe, count and to identify vulture species. Photographs were taken with a camera (Nikon P900). The observation was done from 7:00 in the morning to 17:00 in the evening, in order to cover the period when vultures are most active. To avoid the bias caused by differential detection of species due to visibility distance, observations of vultures recorded at distances beyond 1 km were discarded because of variation in visibility between sites and heat shimmer. Distance was estimated horizontally, i.e. based on the relation to habitats over which vulture species were flying and roosting. Besides, the community managed vulture safe feeding site (Khaireni Community Forest) was also visited to observe their feeding habitat and sites.

Habitat and nesting tree preference

During the survey, habitat types were recorded along with the species recorded. The nest information was collected along with DBH (Diameter at Breast Height (m)) using DBH tape, height of tree (m) using clinometer, nesting height (height of nest above ground (m)), tree type on which nest is built. Preference of tree species by vulture species was recorded by identifying the species where they roosted or nested *(Table 1)*.

Table 1. List of variables used for collecting habitat preference data
1. táblázat Az élőhelypreferencia vizsgálatához gyűjtött változók

Variables	Description
GPS location	–
Habitat type	Forest, Settlement Area, Agricultural land, Rocky and Barren Land, Riverbank
Tree species	Trees used by vultures for nesting and roosting purpose
Tree DBH	Diameter at breast height of both nesting and roosting trees
Tree height	Height of nesting and roosting trees
Distance to water	Distance to the nearest river measured from each point count sites
Distance to settlement area	Distance to the nearest inhabited buildings measured from each point count sites
Distance to farmland/ agricultural land	Distance to nearest farming/agricultural area measured from each point count sites
Distance to forest	Distance to nearest forest area measured from each point count sites
Distance to VSF	Distance to nearest community managed vulture safe feeding site (Khaireni Community Forest) measured from each point count sites
Presence of carcass	Presence of dead livestock

People's perception and practices

A sample questionnaire survey was conducted in the vicinity of their colonies to understand inhabitants' perception about species, carrion disposal practices, livestock holdings and veterinary practice, pesticide, fertilizer and forest resource use. For household surveys, a community managed vulture safe feeding site was taken as the center point and marked the thirty-four households near to the area as site 1. The households within 5 km and the households within 20 km from vulture safe feeding sites were surveyed which resulted in 33 households in each site and were marked as site 2 and 3 respectively. The households were selected based on Random Selection Method (Gupta 2005).

Data analysis

Thematic maps providing roosting and nesting locations of vulture population and species distribution were prepared by using geographical locations. Arc GIS 9.3 was used for the conversion of GPS reading to spatial data layer (point features providing the location). Vulture locations were overlaid on the district map and local unit map.

The vulture species were classified based on different habitat types (i.e. forest, riverbanks, agricultural land, settlement land and rocky/barren land) and were analyzed using MS-Excel and PAST version 3.25. All types of forest were included in forest type habitat; meadows, grassland; the riverbank was included as water dependent land; the agricultural/farmland and settlement habitat; also, rocky and barren area.

Generalized Linear Model (McCullagh 2019), that allowed not only to fit a log-linear model, but also to make the very reasonable assumption, given that the data are counts, that the error distribution is Poisson and not normal (there were large number of zero counts and considerable fluctuations in vulture density) was used for measuring the distance from the nearest water source, distance to forest, agricultural land, settlement area and distance to VSFs in relation to their abundance.

The attitudes of the respondents towards vulture species were measured through questionnaire and combined to form a single attitude scale. Each answer was graded with a number and summed response for each question as positive, negative, and neutral. The non-parametric test, Chi^2 test with 95% confidence interval was used for the association between these variables.

Results

Asian vulture species distribution and abundance

A total of 99 vulture individuals were observed in total 21 points along the Kaligandaki River Corridor. There were 57 individuals from five species (WRV, EV, HG, RHV and SBV) recorded in 12 different points during the summer visit whereas 42 individuals of five species (WRV, EV, HG, RHV and SBV) recorded in nine different points during the winter visit. At the points 14 and 32, vultures were recorded in both seasons. Remarkably only the

Table 2. Total counts of the five vulture species during summer and winter at point count sites in Kaligandaki Corridor

2. táblázat A pontszámlálás során felmért helyeken nyáron és télen megfigyelt keselyűk kumulatív mennyisége

Vulture Species	Summer		Winter	
	Total number of sighting	Total number of individual sighted	Total number of sighting	Total number of individual sighted
Gyps bengalensis (WRV)	9	42	7	29
Neophron percnopterus (EV)	4	7	4	6
Gyps himalayensis (HG)	1	3	1	5
Sarcogyps calvus (RHV)	1	2	1	1
Gyps tenuirostris (SBV)	1	3	1	1
Total	**16**	**57**	**14**	**42**

SBV=Slender-billed Vulture, WRV=White-rumped Vulture, HG=Himalayan Griffon HG, EV=Egyptian Vulture

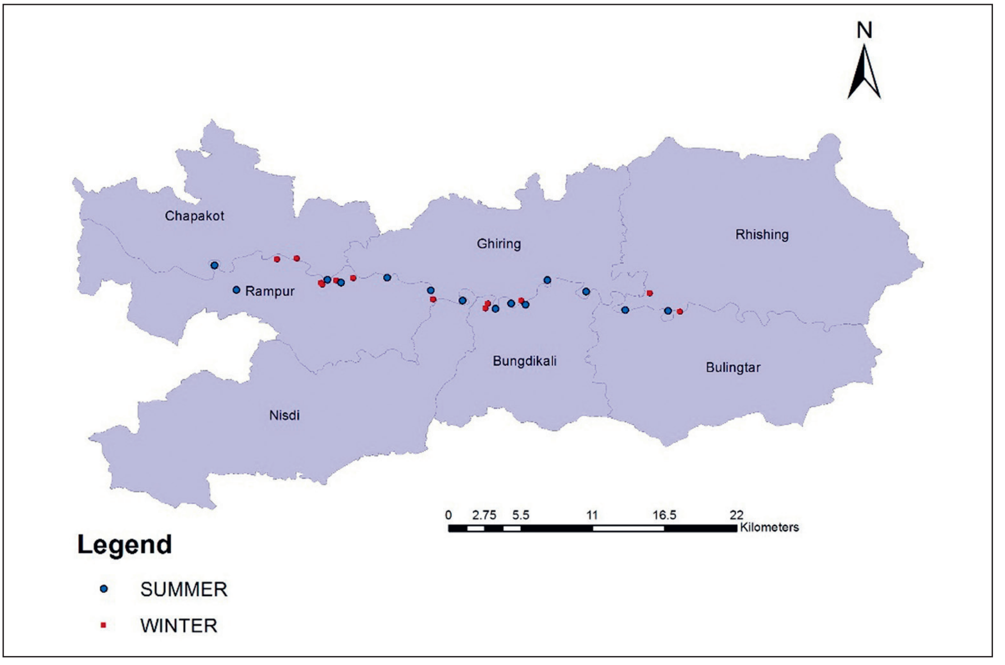

Figure 2. Distribution of vultures recorded in study areas during summer and winter
2. ábra A nyáron és télen észlelt keselyűk megfigyelési helyei

two species, WRV and RHV, were recorded at Khaireni Community Forest with a total of 63 individuals (37 in summer and 26 in winter).

Vulture sightings and abundance had relatively higher frequency during summer, when 57 individuals of five species WRV (42), EV (7), HG (3), RHV (2) and SBV (3) were recorded, as compared to winter season of total 42 individuals with WRV (29), EV (5), HG (6), RHV (1) and SBV (1) in point count sites. WRV was the most abundant species followed by EV, HG, and SBV. RHV was found to be least abundant in point count sites during summer season. During the winter, WRV was the most abundant species followed by HG and EV. Both the RHV and SBV were the least recorded vultures in point count sites. During the summer, vulture abundance was seen highest in point 26 and at point 28 in winter. In Khaireni Community Forest, vulture species were found more abundant during summer with 37 individuals of WRV, than in winter with total 26 individuals of two species WRV (24) and RHV (2). In summer, only WRV was recorded with no records of RHV *(Table 2, Figure 3, 4)*.

Roosting, resting and nesting tree preferences

Vultures were observed roosting and resting in total seven tree species. Trees that were used by the vultures for roosting and resting purposes had an average height of 19 m with DBH of 2.1 m and canopy cover of 35% in other sites. The most favored tree species used for both nesting and roosting were found to be simal, followed by *Ficus* sp. and red cedar *(Thuja plicata)*.

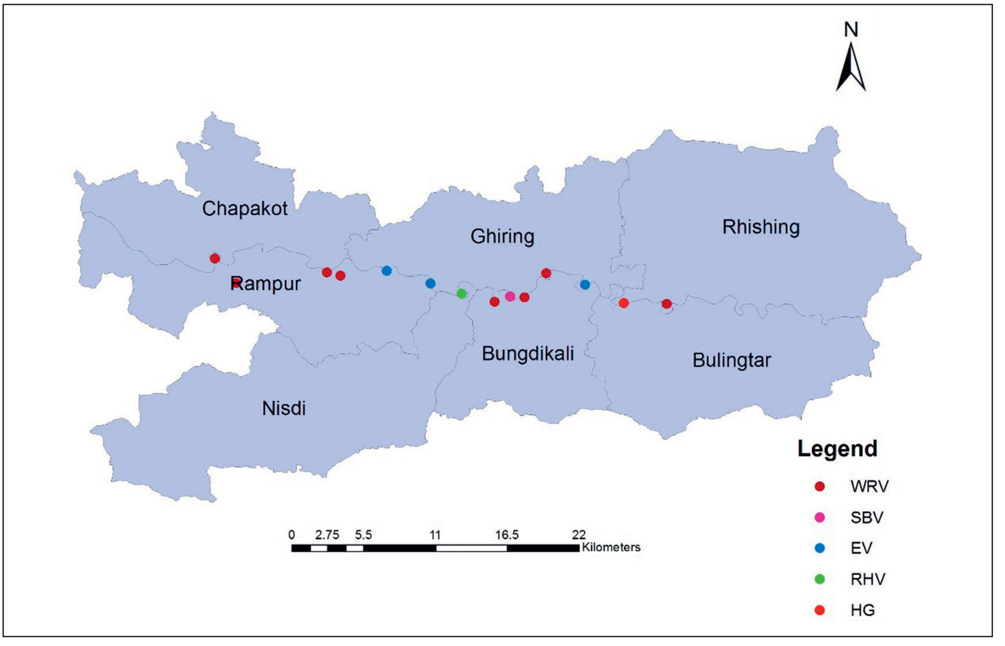

Figure 3. Distribution map of vulture species in summer
3. ábra A keselyűk nyári előfordulási helyeinek térképe

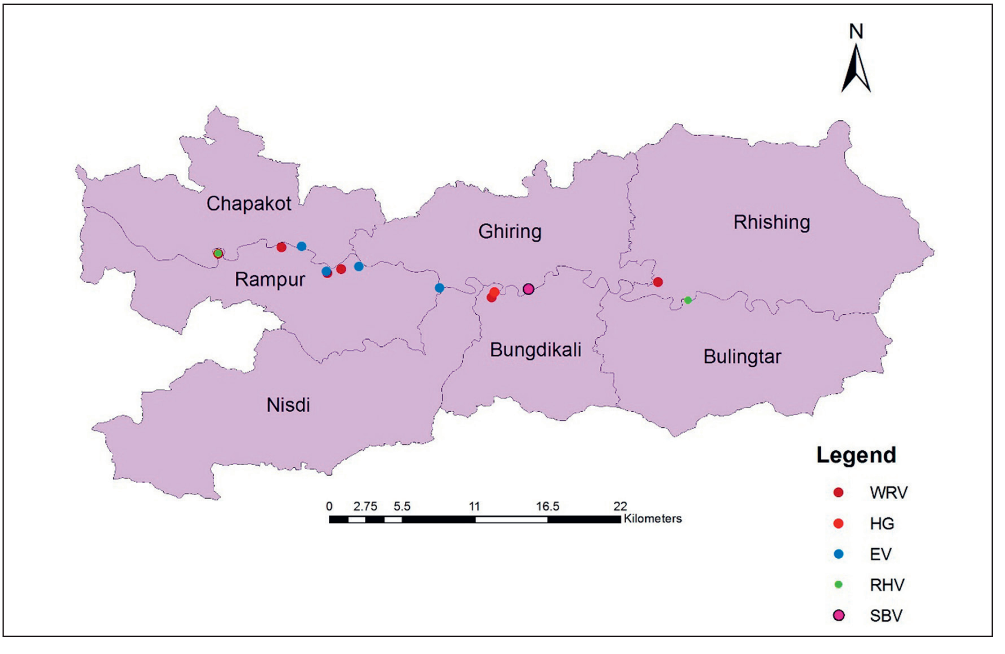

Figure 4. Distribution map of vulture species in winter
4. ábra A keselyűk téli előfordulási helyeinek térképe

A total of 24 nests of WRV (three passive nests and 21 active nests) were recorded in Khaireni Community Forest during winter and summer visit. Also, there was no evidence of nests of Asian vultures from remaining other points during the survey. In Khaireni Community Forest, vulture species were seen roosting and nesting on tall and large trees of simal. Nests were at the top of the tree with an average of 28 m with a tree height of an average 32 m. The average DBH of trees was found to be 4 m. Approximately, 57 trees of simal were found around the nesting area of vulture; however, nest was found to be prepared mostly in a single tree and four nests on two trees. While the roosting trees were of average 17 m height with DBH of 1.3 m *(Table 3)*.

Table 3. Tree species used by vulture for roosting
3. táblázat A keselyűk által éjszakázásra használt fafajok

Tree species	Roosting (%)
Simal *(Bombax ceiba)*	54
Peepal *(Ficus religiosa)*	18
Tuni *(Toona ciliata)*	11
Khair *(Acacia catechu)*	9
Mango *(Magnifera indica)*	8

Habitat preferences

During summer most species sightings were recorded in forest (n=23), followed by riverbank (n=13), agricultural land (n=11), settlement area (n=8) and least in rocky and barren land (n=2). In winter, most vulture sightings were recorded in forest (n=18), followed by agricultural land (n=13), riverbank (n=8), settlement area (n=2) and least in rocky and barren land (n=1). Among recorded species WRV were found abundant in

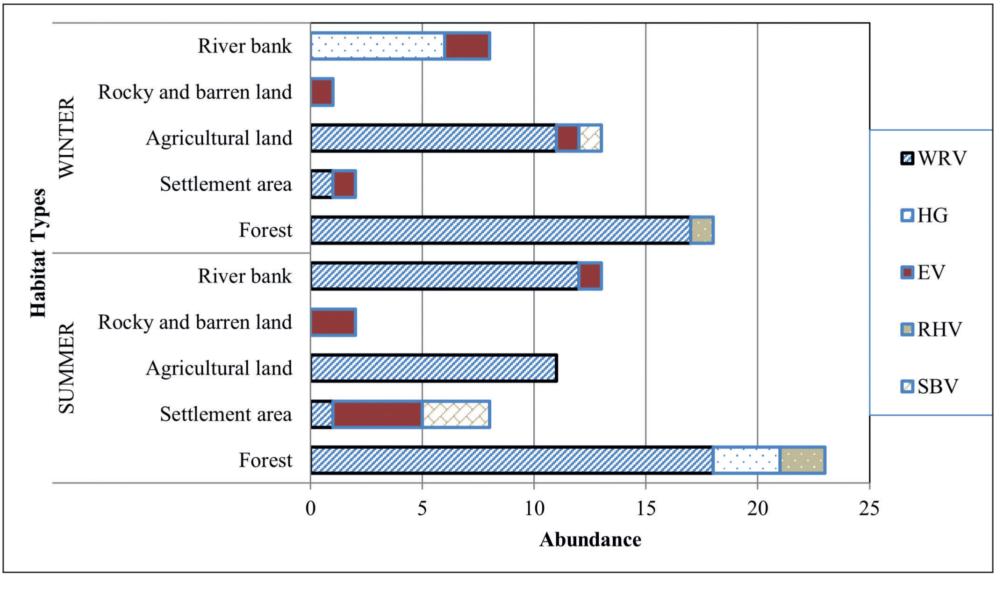

Figure 5. Habitat-wise vulture species abundance for the two seasons recorded at point count sites
5. ábra A keselyűk élőhelyenkénti abundanciája a pontszámlálással érintett helyeken a felmérés két szezonjában

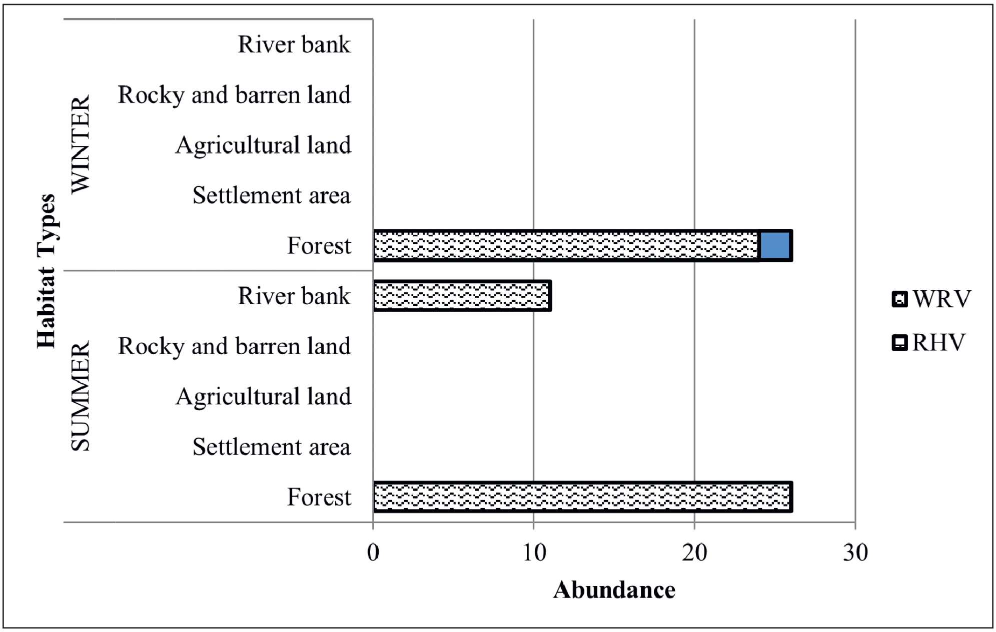

Figure 6. Habitat-wise vulture species abundance for the two seasons recorded in Khaireni community forest

6. ábra A keselyűk élőhelyenkénti abundanciája a Khaireni közösségi erdőben a felmérés két szezonjában

both seasons. EV was only species recorded in rocky and barren land in both seasons. The detailed insight of abundance of different species in different seasons and habitat is provided in *Figure 5* and *Figure 6*. In Khaireni Community Forest, most vulture sightings were recorded in forest areas (n=26), followed by riverbank (n=11) in summer whereas during winter, vultures were found in forest area which is near to the water bank (n=26). Both RHV (n=2) and WRV (n=24) were found roosting inside the forest area in winter.

Table 4. Generalized Linear Model (GLM) showing relation between the abundance of vulture with different environmental variables during summer and winter

4. táblázat Az általános lineáris modell (GLM) eredményei, miszerint a különböző környezeti tényezők és a keselyűk abundanciája között kapcsolat van

Model Parameters	**Summer**				**Winter**			
	Estimate	**S.E**	**Z-value**	**(Pr(>|z|)**	**Estimate**	**S.E**	**Z-value**	(Pr(>|z|)
DW	-0.0010	0.0005	-1.93	0.05	0.0008	0.0006	-1.298	0.194
DS	-0.0014	0.0008	-1.78	0.075	-0.0318	0.0078	-4.053	**0.001**
DA	-0.0129	0.0045	-2.87	**0.004**	0.0003	0.0017	0.203	0.839
DF	-0.0039	0.0014	-2.75	**0.005**	0.0003	0.0007	0.546	0.585
DVSF	1.429e-05	6.78e-06	0.21	0.833	2.711e-04	5.60e-06	4.840	**0.001**

Model parameters: Distance to water (DW), Distance to settlement area (DS), Distance to agricultural land (DA), Distance to forest (DF), Distance to Vulture Safe Feeding Site (DVSF)

Also, WRV were recorded basking near the river bank (n=11) during early morning and were resting in forest habitat (n=26) in summer *(Figure 6*).

Generalized Linear Model showed that the abundance of vulture species was negatively influenced by distance to settlement area (DS) during the winter (z-value=-4.05, p<0.05), distance to agricultual land during summer (DA) (z-value=-2.87, p<0.05), and distance to forest (DF) (z-value=-2.75, p<0.05) during summer *(Table 4)*. The vulture abundance was found to be positevely influenced by the distance to vulture safe feeding site (z-value=4.84, p<0.05). Among the five variables, distance to settlement and distance to vulture safe feeding site showed highly significant relation to vulture abundance in winter. Therefore, these variables are more important in comparison to other variables when predicting vulture species presence in the surveyed area. Generalized Linear Model showed that distance to forest and distance to agricultural land were the important variable along with distance to water in estimating the abundance of vulture species in summer as most of the vulture species with their high number of individuals were recorded in forest, agricultural land and riverbank.

People's perception and practices

Demography of the respondents

Among the total 34 respondents from the Khaireni Community Forest users (site 1), 49% were male and 51% were female. In site 2, 43% were male and 57% were female out of 33 respondents. And in site 3, out of 33 repondents, 52% were male and 48% were female. During the survey, one adult person (>30 years old) in each household was interviewed.

Around 75% of the respondents reared livestock near the community forest (site 1). The preferred livestock type was goat (60%), followed by buffalo (32%), cow and ox (4%). It had been found that general insight about livestock farming had been declining with increasing modernization. Also, within the past seven years, 16% of households lost livestock to disease and 58% of households said they use veterinary services to treat their livestock.

Of the respondents at site 2, it was found that only 56% reared livestock. The most preferred livestock were buffalo (72%) and cow (16%). Also, within the past seven years, 11% of households lost livestock to disease and 43% of households said they use veterinary services to treat their livestock.

Among the respondents from site 3, 91% reared the domestic animals of which preferences of livestock were found to be buffalo (76%), cow and ox (22%), goat (1%). Within the past seven years, 72% of households lost livestock and 69% of households said they use veterinary services to treat their livestock.

During the survey, almost all respondents were known about the vulture species in their area. The respondents had various perceptions regarding the status of their population within seven years of interval. Among the 34 respondents from Khaireni Community Forest users (site 1), 25 respondents said the decrease in vulture species population and seven respondents thought they are increasing and remainining one respondent had no idea on increasing or decreasing population. Similar types of result was found in remaining two sites. Among the respondents of site 2, thirty respondents had viewed on decreasing of vulture species population and remaining had no perception on increasing or decreasing population in their area. Among the respondents from site 3, 31 respondents had said that vulture species were decreasing in their area. Besides two respondents had no views on increasing or decreasing population of vulture species.

The Chi^2 test was applied to compare the status of their population within seven years in different sites, as respondents answer showed there was a significant difference in people perception of three different sites on their population status *(Table 5)*.

Table 5. Comparing the people's perception of three different sites on vulture population
5. táblázat Az emberek elképzelése három különböző hely keselyű populációjáról

Site	People's perception on vulture population	Respondents, (%)	x^2	p-value
Site 1 (n=34)	Increasing	20.6	29.6	0.05
	Decreasing	73.5		
	Neutral	5.9		
Site 2 (n=33)	Increasing	0	8.7	0.05
	Decreasing	90.9		
	Neutral	9.1		
Site 3 (n=33)	Increasing	0	9.5	0.05
	Decreasing	97		
	Neutral	3		
	Grand total	**300**	**47.6**	**0.02**

People's perception

According to the respondents of site 1, 67.64% said food scarcity (less carrion amount) as a major reason for decreasing the vulture population followed by deforestation (20.58%) of large and nesting trees as second major threats. Among the participants, 8.83% of respondents said decline due to use of chemicals and pesticides with remaining 2.94% on lack of conservation awareness. In site 2, food scarcity (45.45%) due to the practice of burying the carcass, providing carcass to skin tanner, modernization was found as a major threats on decline of vulture population followed by habitat loss/destruction (30.30%). Lack of conservation awareness (12.12%), use of chemicals and pesticides (12.12), were also the reason behind the decline of vulture population in site 2. Among the participants at site 3, food scarcity (51.51%) due to low livestocks rearing practices, lack of conservation awareness (18.18%), hunting (12.12%), habitat loss (12.12%) and poisioning with use of chemicals and pesticides (6.06%) were the major cause for decline in vulture population and consider as a major threats.

The Chi^2 test was applied to compare the response of participants of three different sites regarding on threats for vulture species. The Chi^2 test showed that the estimated value was greater than tabulated value, which means there was a significant difference in people perception of three different sites on threats to vulture species *(Table 6)*.

Table 6. Comparing the people's perception of three different sites on threats for vultures
6. táblázat Az emberek elképzeléseinek összehasonlítása a keselyűket veszélyeztető tényezőkről

Sites	Threats	Respondents(%)	x^2	p-value
Site 1 (n=34)	Food scarcity	67.6	13	0.049
	Habitat loss	20.6		
	Lack of conservation awareness	2.9		
	Use of chemicals and pesticides	8.8		
	Hunting	0		
Site 2 (n=33)	Food scarcity	45.5	10.9	0.049
	Habitat loss	30.3		
	Lack of conservation awareness	12.1		
	Use of chemicals and pestticides	12.1		
	Hunting	0		
Site 3 (n=33)	Food scarcity	51.5	25.8	0.049
	Habitat loss	12.1		
	Lack of conservation awareness	18.2		
	Use of chemicals and pesticides	6.1		
	Hunting	12.1		
	Grand Total	**300**	**49.7**	**0.05**

Estimate Value of Chi^2 test was 49.7 with tabulated value of 15.507

Among the respondents from site 1, every respondent thought that vultures are useful for the environment. When the respondents were asked about the efforts for their conservation, the majority of respondents (81%) suggested that the management of vulture safe feeding sites through governmental aid, increased food availability and community participation would be needed. Most respondents (>93%) from site 2 also had positive responses on usefulness of vulture species in environment and suggested the provision of carcass disposal along with habitat conservation efforts. Similarly, 45% of the respondents from site 3 had a positive response towards the vultures as they thought of as useful birds. The remaining 30% of the respondents thought vulture species as a bad sign and were dirty birds while 25% respondents do not have any such perception. For the conservation efforts, the respondents suggested the management of carcass disposal practices through community participation along with governmental aid.

Carrion availability and disposal practices

Carrions were only found in the community managed forest: two carrions were identified as ungulate and two others were unidentified, as only bones were found.

After the death of the livestock, the users, and the households nearer to Khaireni Community Forest (site 1) managed the carrion by taking it to the vulture safe feeding site (100%). In site 2, 34% of the carrions were buried, 24% were thrown on river, 16% were given to skin tanner and 7% were taken to community managed vulture safe feeding site.

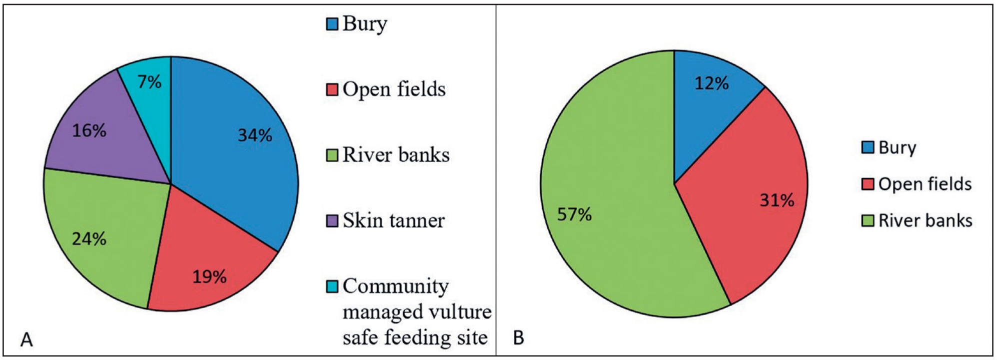

Figure 7. Carcass management practices done by respondents in site 2 (A) and site 3 (B)
7. ábra A válaszadók által alkalmazott tetemkezelési gyakorlatok a 2. (A) és a 3. (B) helyszínen

The carrion was dumped in various places based upon the easy access of dumping sites. Besides, the households far from vulture safe feeding site (site 3), carrion were disposed of by throwing in riverbanks (57%), open areas (31%) followed by burying practices (12%). The carrion disposal practice applied by respondents after the death of the livestock in site 2 and 3 has been illustrated in *Figure 7*, where burying practices and throwing in riverbanks were seen higher**.**

Discussion

Our survey recorded 162 individuals from five Asian vulture species. Vultures were observed in 13 locations during summer and in 10 locations during winter (including KCF). In KCF, both WRV and RHV were seen in winter, while only WRV was recorded in summer, probably due to overlapping foraging and observation times. The presence of these species along the Kaligandaki River may be related to the availability of food, water, and suitable roosting and nesting locations. Given that the majority of vultures were observed flying, soaring, or basking, migration from other regions may be feasible. For more than ten years, KCF has been the ideal location for nesting due to its mature simal trees, easy access, and low level of human disturbance (Gautam & Baral 2014). Solid-waste dumping sites or nests may be the cause of recurring presence in both seasons.

Vulture species abundance was higher in summer than in winter at both observation sites and in KCF, likely attributed to their breeding season, a pattern which aligns with the findings reported by Manandhar *et al.* (2019). Also, during the study period in and around the vulture restaurant, five species of Asian vultures were recorded except GV at Pithauli, Nawalparasi (Adhikari & Bhattarai 2017), which is the closest habitat of these species that lies in the eastern part of study area which shows similar findings.

Vulture species abundance was highest in the Siun region, with high counts observed at Point 26 and Point 28, both in summer and winter, particularly due to area's rich habitat features which includes large trees such as simal, chilaune, mango *(Mangifera indica),* peepal *(Ficus religiosa)* for roosting and nesting with easy access to food and water resources.

The higher abundance of WRV may be due to their relatively dense population in KCF and potential movement from nearby vulture restaurants and safe feeding zone.

Communal roost sites are also regularly used by WRV (Gilbert *et al.* 2006). The availability of nesting and roosting trees such as simal, peepal, and saaj, along with open dumping sites, facilitates higher presence of WRV.

Similarly, Baral and Gautam (2007) also reported that 92 and 51 were the maximum and minimum population of WRV recorded in the months of October and March respectively in the Palpa District (Rampur valley) which occupies half of our study area. However, RHVs were least abundant, probably due to their restricted habitat and rare tendency to gather in groups.

KCF holds the highest nesting sites with total of 24 nests (21 active nests and three passive nests). Similarly, Ghimire *et al.* (2019a) also recorded 21 WRV nests in KCF in which 17 (81%) nests were active and four (19%) nests were passive in that breeding season, with all nests found in simal trees except one, which was in tuni tree. The average nest height in our study was 32m, like the previous study (Subedi 2008). According to (Rana *et al.* 2019), WRVs typically nest on tall tress having greater diameter for nesting, roosting and perching, usually one nest per tree. However, we observed five active nests in a single tree.

Vulture species have a large territory and travel far for feeding, which may explain the absence of nest in the other sites. Low number of nests were observed which might be due to the survey period during the pre-breeding season when vulture species indicated the early breeding activity. Among the tree species, Simal was mostly used for nesting and roosting, followed by peepal and tuni. The preference of open grassland with scattered trees at forest edges or in lightly wooded forest aligns with the previous findings (Rana *et al.* 2019)**.** The study area falls under subtropical regions and has a good coverage of broadleaved forest, provides favorable habitat for many of the species including these endangered vulture species. Besides this, *Gyps* vultures are known to nest in a variety of trees viz sal, peepal, bar *(Ficus benghalensis)*, silk tree *(Albizia julibrissin)*, mango, emili *(Tamarindus indica)*, sisaoo *(Dalbergia sisoo)*, neem *(Azadirachta indica)*, eugenia tree (*Syzygium* spp.), saaj *(Terminalia elliptica)* (BirdLife International 2021). Among these, silk cotton trees are observed to be the most preferred tree species by vulture species, serving as roosting, perching and nesting sites. Tall forest trees (>10 m) and elevated ledges/caves/crevices (≤ 25 m) offered refuge from predators, and foraging platforms (Campbell 2015). Large trees (Chhangani 2007, Dhakal *et al.* 2014) provided predator avoidance, suitable microclimates (Campbell 2015) and increased mobility (Wright *et al.* 1986) for vultures.

Although vulture sightings were seen highest in forest followed by agricultural land, riverbank, settlement areas and rocky and barren land during the study period, all such habitats were being used for nesting and roosting purpose by different species of vulture. In summer, at point counts, abundance of vultures was found in forest habitat followed by riverbank habitat as roosting and nesting occurred on trees (forest) and cliffs, while water bodies were used for drinking. Likewise, in winter, abundance was found higher in forest followed by agricultural land, human settlement area and rocky and barren land. In KCF, vultures were also found resting and roosting inside the forest areas which lie near the riverbanks. Vultures were also found basking near the riverbanks during summer visit whereas during the winter, most of the vultures were resting and roosting on the trees and caring for the nests. Vultures are also known to colonize wooded as well as open habitats with agriculture and tree cover (Donázar *et al.* 2002a, 2002b). Vultures preferred areas associated with rivers, agricultural fields and grasslands, and open forest, when these were at relatively low elevations (<1000 m) and were close to paths, water and settlements. Baral and Inskipp (2004) also found that vultures prefer habitat with combination of outskirts of village, solid waste dumping site, tall and strong trees and enough sources of water, which supports similar results to the study.

WRV were found maximum in forest followed by riverbank and least in agriculture and settlement land areas with no occurrence in rocky and barren land in summer at point count sites. WRV frequents cultivation, open country and around human habitation (Inskipp *et al.* 2016). WRV breeds in colonies in tall trees such as simal and peepal, often near human habitation (Subedi 2008). HG inhabits grasslands, temperate-grasslands and rocky areas such as cliffs and mountain peaks. Breeding occurs between 600–4,500 m. Non-breeding birds migrate to lower altitudes to spend the boreal winter in the plains (Li & Kasorndorkbua 2008). EV were found more in settlement areas due to the proximity of dumping sites near the human settlement. EV in the mid-hills of Nepal, preferred sites near to settlements reason for this association was them being attracted by available livestock carcasses, one of the main sources of food (KC *et al.* 2019). Also only the EV were recorded at rocky and barren land preferring the cliffs for roosting and nesting purpose. SBV frequents cultivation, open country and around habitation, especially villages. RHV are mostly found in open country near habitation, wooded hills, and dry deciduous forest with rivers (Birdlife International 2017). Bhusal *et al.* (2019) also found that SBV uses open country mixed with some wooded patches to forage, feed, roost and nest and inhabit open forests up to 1,500 m in the vicinity of human habitation (Grimmett *et al.* 2000). It is a carrion feeder often scavenging at rubbish dumps and slaughterhouses. KC *et al.* (2019) found that vultures preferred the areas near to the distance to water, distance to settlement because of the easy access of food and water, which shows similar findings to the study. Also, for the roosting purposes they select the nearest forest habitat. The reason behind the association of vultures with distance to VSF might be the easy and higher chance of carrion access in the vulture safe feeding site. Many studies support the impact of feeding stations in facilitating recolonization of scavenging raptors (Mundy *et al.* 1992, Oro *et al.* 2008, Lieury *et al.* 2015). The possible reasons for the correlation of presence of active nests with distance from the feeding station could be reduction in the foraging time due to proximity to the feeding station and the availability of food at feeding stations which reduces the risk of mortality (Snyder & Snyder 2005).

The availability of food sources is one of the main elements influencing vulture abundance. The study discovered that burial has replaced open dumping as the method of disposing of carcasses, which restricts vultures' access to food. Food scarcity is a result of this transition, which is being fueled by modern agricultural methods and worries about the spread of disease (Ghimire *et al.* 2019b). Policymakers and conservationists should support sustainable carcass disposal methods, such community-managed designated feeding stations, to solve this. Reliance on haphazard carcass disposal might be decreased by establishing well-regulated Vulture Safe Feeding Sites (VSFS), which would guarantee a steady and secure food source. To increase their efficiency, these locations should also be placed far from human disturbances and close to vulture nesting places.

The VSFS managed by local communities has been mostly effective (Mahaseth 2024). Community driven strategies for conservation in Nepal are exemplary, as the system of community forests of Nepal is recognized as a conservation success worldwide. Protection of community forests fosters the conservation of vultures. Strategies of vulture conservation using community driven strategies are more effective since it develops the feeling of own responsibility.

Vulture conservation in Nepal has benefited from community-managed Vulture Safe Feeding Sites (VSFS). In contrast to vulture restaurants run by NGOs in India, Pakistan, and Africa, Nepal depends on community-driven initiatives, which have been successful. Outside of protected regions, where human disturbances provide a concern, conservation initiatives are still few. On the other hand, artificial breeding grounds and nesting platforms have been successful in the United States and Europe (Kluever *et al.* 2020). Vulture conservation in Nepal can be improved by creating protected areas and mapping possible nesting locations, as has been done effectively in India (Majgaonkar *et al*. 2018, Jha *et al.* 2021).

The use of diclofenac is strictly regulated by the European Union (EU). The governments were successful in protecting vultures and are keeping a close eye on the extensive feeding grounds to ensure long-term viability. The vulture population has been successfully stabilized and rebuilt as a result in natural parks of northern Spain (Cortés-Avizanda *et al.* 2015). Food scarcity and habitat loss were regarded as the major reason for population decline in all sites of the recent study, whereas lack of conservation awareness was seen more in site 3 followed by site 2, as no conservation practices are done in those areas. Ethnicity, age, education, gender, occupation, etc. are the significant factors that govern the conservation attitudes (Baral & Gautam 2007). The association between the attitude of people and their view on conservation proves that people having a positive attitude towards vulture are willing to conserve them more. Also, due to the awareness program and conservation strategies, users of Khaireni Community Forest had more positive attitudes in comparison to other sites. It was found that Khaireni Community Forest played a significant role in changing the perception of people towards vulture conservation. So, education regarding the importance of vulture in the environment and the impact in the environment without vultures should be given to local people in other two sites.

Although people around the Khaireni Community Forest were seen aware of vulture conservation, the small number of carcasses and uneven management of the feeding site were regarded as the major threats and reason of vulture decline in the area. According to Ghimire *et al.* (2019b) food scarcity, habitat loss and electrocution were considered as the threats for vultures. They found good level of awareness towards vultures and their declining population, and they asked for similar conservation strategy by the locals at core breeding area of Rampur IBA, Palpa, Nepal. The reason for decline in vulture population was similarly connected with food scarcity and habitat loss; however, effect of electrocution was not seen as a major cause during the study period which could be the difference of respondents view and survey sites. Uses of chemicals and pesticides were seen more on site 1 as the people on this site rely more on agriculture than on the other sites. According to the respondents from site 3, hunting practices were recorded as major threats along with food scarcity and habitat loss. Due to the lack of conservation awareness, hunting practices were recorded. Use of veterinary drugs, ingestion of chemicals and lead, poisoned bait, anthropogenic climate change, nonfood items, low food availability and deforestation threatened the vultures (Harris 2013). Although most of the previous studies showed the use of diclofenac as the main threats for vultures, there was not any record of use of diclofenac in the study area. The absence of diclofenac impact may be due to the ban on import and production in Nepal. Besides these, excessive use of chemicals and pesticides in agriculture, lack of conservation awareness and hunting are creating unfavorable conditions for vulture's existence in the area which shows similarity with others' results.

Conclusions

The study shows that there was strong influence of season on vulture species abundance due to the breeding activities and carrion availability. Particularly WRV, preferred habitats with tall nesting trees like *Ficus*, *Toona*, and *Bombax*, highlighting the importance of conserving these tree species. A significant number of WRV and RHV in the vulture restaurant inside KCF underscores its importance as a critical habitat. It also highlights the success of community-led management practice and demonstrates the role of local people involvement in conservation. Further, strengthening conservation awareness campaigns can boost public understanding of ecological role of vulture species in carrion removal and disease control.

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Appendix 1. Distribution of vulture species during summer visit
1. melléklet A keselyű-megfigyelések földrajzi eloszlása a nyári időszakban

SN	GPS	Point count site number	Location	Species recorded	Number of individuals
1	27.86111°N 83.86472°E	2	Ratomata	WRV	1
2	27.86817°N 83.92726°E	14	Gandakidhik	WRV	3
3	27.86613°N 83.9366°E	15	Nisdi river bridge	WRV	3
4	27.86941°N 83.96839°E	19	Veltar	EV	2
				WRV	5
5	27.86065°N 83.99841°E	22	Puttarghat	WRV	9
6	27.8536°N 84.01998°E	26	Damaraphat	RHV	2
				WRV	11
7	27.85176°N 84.05356°E	30	Bhantar bazar	SBV	3
				WRV	2
8	27.86782°N 84.07832°E	31	Dedgaun	WRV	1
				EV	1
9	27.85097°N 84.0633°E	32	Dedgaun	EV	2
10	27.85977°N 84.10491°E	37	Machedi	EV	2
11	27.84717°N 84.1317°E	42	Ramjakot	HG	3
12	27.84651°N 84.16135°E	47	Bulingtar	WRV	7

SBV=Slender-billed Vulture, WRV=White-rumped Vulture, HG=Himalayan Griffon, EV=Egyptian Vulture, RHV=Red-headed Vulture

Appendix 2. Distribution of vulture species during winter visit
2. melléklet A keselyű-megfigyelések földrajzi eloszlása a téli időszakban

S.N.	GPS Points	Point Count Site number	Location	Species Recorded	Numbers of individuals
1	27.88294°N 83.90641°E	8	Sakhar	WRV	5
				EV	1
2	27.86472°N 83.92389°E	13	Sadawarta	WRV	1
				EV	1
3	27.86758°N 83.93343°E	14	Nisdi river	WRV	11
4	27.86912°N 83.94511°E	16	Baidi pul	WRV	4
5	27.85444°N 84.00015°E	23	Puttarghat	WRV	2
				EV	2
6	27.85177°N 84.03776°E	28	Khukuritar	HG	5
				EV	2
				WRV	3
7	27.8536°N 84.06053°E	32	Dedgaun	SBV	1
8	27.85882°N 84.14876°E	44	Bhirkot	WRV	3
9	27.84599°N 84.16933°E	48	Bulingtar	RHV	1

SBV=Slender-billed Vulture, WRV=White-rumped Vulture, HG=Himalayan Griffon, EV=Egyptian Vulture, RHV=Red-headed Vulture